UNCLASSIFIED

AD NUMBER	
ADA492284	
CLASSIFICATION CHANGES	
TO:	**UNCLASSIFIED**
FROM:	**CONFIDENTIAL**
LIMITATION CHANGES	
TO: **Approved for public release; distribution is unlimited.**	
FROM: **Distribution authorized to DoD only; Foreign Government Information; SEP 1952. Other requests shall be referred to British Embassy, 3100 Massachusetts Avenue, NW, Washington, DC 20008.**	
AUTHORITY	
DSTL ltr dtd 16 Feb 2007; DSTL ltr dtd 16 Feb 2007	

THIS PAGE IS UNCLASSIFIED

12/52

~~CONFIDENTIAL~~

COPY No. 43

LIMITED DOCUMENT. NOT TO BE DISTRIBUTED FURTHER

MINISTRY OF SUPPLY

ARMAMENT RESEARCH ESTABLISHMENT

REPORT No. 12/52

WEAPONS RESEARCH DIVISION

Controlled Fragmentation, XXXII.

The Application of the Grooved-charge Principle to Spin-stabilised Shell, III.

H. Titman and T. W. Taylor
Safety in Mines Research Establishment, Buxton

LIMITED DOCUMENT. NOT TO BE DISTRIBUTED FURTHER

Fort Halstead
Kent.

~~CONFIDENTIAL~~

September 1952

This Document was graded
CONFIDENTIAL
at the 52nd meeting of the A.R.E.
Security Classification Committee.

A.R.E.
Publishing Section

CONFIDENTIAL

MINISTRY OF SUPPLY

Extra-mural research contract

with

SAFETY IN MINES RESEARCH ESTABLISHMENT, BUXTON

A.R.E. REPORT No. 12/52

Controlled Fragmentation XXXII. The application of the grooved-charge principle to spin-stabilised shell, III

by

H. Titman, B.Sc., Ph.D. and T.W. Taylor, B.Sc.

CONTENTS

Approved

W. C. F. Shepherd .... for Director, S.M.R.E.

W. Blackman .... Senior Superintendent, A.R.E.

Buxton Report No. E.197 May, 1952

CONFIDENTIAL

IMPORTANT

This DOCUMENT should be returned to the Chief Information Officer, Armament Research Establishment, Fort Halstead, Sevenoaks, Kent, if retention becomes no longer necessary.

INITIAL DISTRIBUTION

Internal

No. 1	CSAR
2	SEMP

United Kingdom

3 - 4	CS/ERDE
5	DWR(D)
6	SSPR
7 - 8	SFP
9 - 18	Director, SMRE
19 - 20	Dr.H.Titman, Mr.T.W.Taylor
21	CEAD
22 - 23	Secretary, A.A.Lethality Committee (O.B.)
24 - 25	Secretary, Weapons Research Committee
26 - 27	Commandant, MC of S
28 - 29	Commandant, Roy. Sch. Tank Technology
30	DGPV
31	DRAE(GW)
32	Sec.OB
33	Sec.OB (Mr. Bishop)
34	Professor Pearson

Overseas (through TPA3/TIB)

35 - 52	US - Joint Reading Panel
53	- R & D Board
54	- Applied Physics Laboratory, John Hopkins Univ. (Attention Dr.C.F.Meyer)
55	- Ballistics Research Lab. Aberdeen (Attention Dr.T.E.Sterne)
56	- Naval Ordnance Lab. Exp. Div. (Attention Dr. Paul Fye)
57 - 60	BJSM (incl. Naval Staff)
61	Canada - Dept. Nat. Def.
62 - 65	- Def. Res. Liaison
66	- Nat. Res. Council
67 - 71	Australia - Sen. Rep.
72	- RAAF
73 - 74	TPA3/TIB - Retention

Stock

75 - 84

[redacted]

SUMMARY

The investigation into the application of the grooved-charge method of controlling fragmentation to spin-stabilised shell has been continued with the 3-in. 70 cal. shell to design D2(L)5851/GE/880. An attempt has been made to obtain full-length bar fragments, but only half-length bars were obtained.

The failure was probably due to the presence of a forward driving band, but the results have also indicated a need for further research with parallel-walled canisters of similarly hard steel.

INTRODUCTION

The object of the experiments was to split a shell into a few fragments which would be the full length of the shell. The 3-in. 70 cal. shell to design D2(L)5851/GE/880 was chosen: it is comparatively thin-walled and is manufactured from 45-ton steel having a hardness of 310 V.D. hardness number. The steel is thus harder than any used in previous applications of the grooved-charge principle. This shell is fitted with a forward steel driving band between the nose and the normal copper band: at this point the wall of the shell is thinned considerably.

Full-length fragments have previously been obtained from parallel-walled canisters of both mild steel and medium carbon steels of hardness 200-250 V.D. hardness number (Shepherd & Haig, 1943; Shepherd & Gibson, 1952). No attempt, however, has been made to produce long fragments from shaped canisters in which the charge/weight ratio is continuously variable along the length. It was realised, therefore, that there were several factors present that might cause difficulty in producing full length fragments, namely (1) hard steel (2) variable charge/weight ratio and (3) a point of weakness in the wall caused by the forward driving band half-way along the shell.

EXPERIMENTAL

A grooved charge for a shell can only be obtained by using the rubber liner technique (Shepherd & Gibson, 1952). Fragments having a square section were desired, and since the wall thickness over most of the middle portion of the shell was 0.275 in. it was decided to use 25 flutes round the charge: the depth of flute was 0.12 in. and the apical angle 75 degrees.

The contour of the cavity in the shell is smoothly curved, but it was noted from the drawings that it consisted essentially of four main sections. At the base there was a small hemispherical portion which was followed by a longer conical section: the central length of the shell was cylindrical, and then at the nose there was another conical section. It was thought that a rubber liner would be sufficiently flexible to accommodate itself to the shape even though it was made on a former in which there was not a smooth change from one section to another.

A former based on the principle described by Shepherd & Gibson for barrel shapes was designed for the shell, and full working drawings were prepared by the Armament Design Establishment. The dimensions of the former were such as to allow a liner 0.015 in. thick to just fit the smallest cavity permitted by the dimensional tolerances on the shell. A mild steel former was manufactured at Buxton and used for the preparation of flexible rubber liners: Fig.1 shows both the former and a liner.

Operationally, this shell may have a deep intrusion in the filling. It was found that the thickness of explosive annulus around the intrusion was only about 0.4 in. and this was further reduced by the flutes of the rubber liner. For these experiments, therefore, a filling of 50/50 RDX/TNT was chosen since this was sufficiently fluid when molten to flow into the narrow annulus. Initiation of the charge was by means of two 14 dr. (1.4 in. diameter) C.E. pellets at the bottom of the cavity. The upper pellet was holed to allow a No.6 aluminium-cased ASA detonator to pass through and touch the upper face of the lower solid

[redacted]

pellet. The point of initiation was thus approximately 4 in. below the nose. For later experiments it was decided that the deep intrusion was not an essential part of the experiment, and the two C.E. pellets were then inset in the charge right at the nose of the shell.

The supply of these shells was very limited and for some of the experiments it was necessary to use shells that had been recovered after firing with inert filling in gun trials. The inert filling was steamed out and the nose adaptors were modified to suit the depth of intrusion required in the present experiments. It has previously been found that there was no significant difference between the controlled fragmentation of new shells and similar shells fragmented after recovery from gun trials (Titman & Taylor, 1951).

All the shells were fragmented under standard conditions in the large sawdust pit, and the fragments were separated magnetically.

RESULTS

In order to assess the effectiveness of control it is necessary to know the natural fragmentation of the shell under comparable conditions. Detailed weighing reports of the natural fragmentation of a shell without a liner and the controlled fragmentation with different liners are given in the Appendix. The fragments showing threads from the nose and those pieces of the copper and steel driving bands that could be identified are shown separately in the Tables. Because it was made of steel it was not always possible to identify all the pieces of the forward band.

Shell A contained no liner and shells B_1 and B_2 contained a liner having 25 flutes as originally designed: the filling in each case had deep intrusion of the fuze. It is clear that the liner exerted a considerable effect on the fragmentation. From shell A there were only six fragments that individually weighed more than 1 oz. (these were all from the base of the shell) whereas from shell B_1 there were 20 fragments, and from shell B_2 23 fragments, in this class: the fragments weighing more than 1 oz. from shells A and B_2 are shown in Figs. 2 and 3. Shells B_1 and B_2 were used in repeat trials; visual examination of the controlled fragments from the former indicated that the cut in the steel had not been as deep or effective as had been anticipated, and it was thought that, perhaps during filling of the charge, there might have been a partial collapse of the flutes. This is liable to occur with this particular type of rubber latex if the head of liquid explosive is allowed to exceed 3 in. during the filling process. There is no measurable distortion of the flutes if the head of liquid is kept below this level. The shot was therefore repeated with very careful filling, but the result was not significantly different.

Although the fragmentation had been very considerably modified by the liner the main object of the experiment had not been achieved. The cuts in the steel were too shallow and the fragments were short and of triangular cross-section. It was thought that this fault might be overcome by increasing the distance between the flutes. The former was therefore modified by filling alternate grooves with plasticine, so producing a liner having 13 flutes instead of 25. The technique of nose initiation was also adopted, thus ensuring that over the whole length of the flutes there was sufficient explosive to cause the full cutting action in the steel.

The result of the first shot with 13 flutes (shell C) is given in the Appendix and the fragments weighing more than 1 oz. are shown in Fig.4. There were several fragments with the full thickness of the wall, but still many having a triangular section; none were the full length of the shell.

It was therefore decided to modify the liner still further by making the 13 flutes 0.18 in. deep, as compared with the original depth of 0.12 inch. The result of this shot is given as shell D and the fragments are shown in Fig.5. Control was much more effective, almost 35 per cent. of the total weight of the shell being represented in fragments weighing more than 1 oz.; there were still many fragments of triangular section and there were none of full length. At one end of most of the fragments there was part of the recess turned out of the shell wall to accommodate the forward driving band, and it was obvious that this point of weakness was preventing the formation of full-length fragments.

The results indicated that it was difficult to control the fragmentation of this very hard steel. This conclusion was confirmed in two ways. Firstly, a shell was softened by suitable heat treatment to a hardness of 200 V.D. and was fitted with a liner having 13 flutes each 0.12 in. deep; it was thus directly comparable with shell C. The fragmentation result is given in the Appendix as shell E and the fragments weighing more than 1 oz. are shown in Fig.6, which should be compared with Fig.4. Control was certainly much better with the softened shell and was, in fact, as effective as with the liner having 0.18 in. flutes in the hard shell (shell D). The fragments had a better shape and showed less chipping from the outer faces, but there were still no full-length fragments.

The second test of the effect of hardness on control was carried out with parallel-walled canisters, 2.90 in. internal diameter, 12 in. long and wall thickness 0.40 inch. Full-length fragments had previously been obtained from a mild steel canister of this size by means of a rubber liner (Shepherd & Gibson, 1952) and similar liners were now used in medium carbon steel canisters heat treated to hardness of 200 V.D. and 310 V.D. number. Full-length fragments were obtained in all cases: those from the medium hard canisters were almost indistinguishable from those from the mild steel; the fragments from the hard canister, however, showed more chipping along their outer faces, indicating that control was slightly less efficient. It must be emphasised, however, that unbroken full-length fragments were obtained and the slight loss in efficiency was represented only by a loss in weight from chipping.

DISCUSSION

In all cases the use of a fluted rubber liner considerably coarsened the fragmentation of the shell, but the desired full-length fragments were never obtained. The harder steel seemed to be more prone to shear at an angle of 45° to the wall and, when 25 flutes were used, almost all the fragments were of triangular cross-section. Even when 13 flutes were used a large triangular fragment was formed between each pair of primary fragments.

An improvement was noted when the shell was softened and its hardness reduced to 200 V.D., the triangular chipping from the outer face being less and the cut in the steel slightly deeper for a given flute depth.

The experiments with parallel-walled canisters show, however, that the slightly shallower cut and the tendency to 45° shear in the hard steel do not account for the failure to produce full-length rods. Two factors may be jointly responsible. Along the length of the shell the shape of the cavity and the varying thickness of wall combine to create a continuously varying C/W ratio, with the highest value along the middle portion of the charge. Thus there is a tendency for the fragments to be unevenly stressed during formation and when the variation of stress is too great the fragments break. The second factor, however, is probably predominant. In this particular design of shell, a forward driving band is fitted, and this is pressed into a deep groove around the wall at the point where the C/W ratio is already tending to cause breakage. Many of the controlled fragments were about 3-1/2 in. long and almost all of them showed, at one end, a portion of this groove. It seems doubtful therefore if full-length fragments can be obtained by means of a fluted liner in any shell that needs a forward driving band. It is clear, however, that flexible liners can be made to modify the natural fragmentation though the limitations cannot yet be specified. Further fundamental work is required in order to decide the depth of flute necessary to obtain good control of very hard steels.

It is worth noting that the clearly defined cuts in the steel indicated that the flutes in the rubber liners had not collapsed during the filling process and that the rubber bag had expanded to the shell wall.

CONCLUSIONS

1. A fluted rubber bag can be successfully made to fit the internal contour of a shell.

2. It is doubtful if full-length fragments can be produced by this means from a shell that has a forward driving band.

3. Even though full length fragments were not obtained there was considerable control of the fragmentation of the shell.

4. More fundamental work is required with parallel-walled canisters in order to determine the relationship between optimum groove depth and hardness of steel.

REFERENCES

Shepherd, W.C.F. & Haig, J., 1943; Buxton Report No. E.81, Ministry of Supply A.C.4141

Shepherd, W.C.F. & Gibson, J.W., 1952; A.R.E. Report No.18/51

Titman, H. & Taylor, T.W., 1952; A.R.E. Report No.1/52

APPENDIX

SHELL 3 in. 70 cal. to design D2/L/5851/GE/880

EXPLODER Two 14 dr. pressed C.E. pellets: upper one holed to take No.6 A.S.A. detonator

FILLING 50/50 RDX/TNT filled at Buxton

LINER For controlled fragmentation: design as specified below
Revertex rubber liner 0.015 in. thick

Identification of shell	Liner	Point of initiation	Expt. No.
A	Natural: no liner	Deep intrusion	B1610
B1	25 flutes 0.12 in. x 75°	" "	B1605
B2	25 flutes 0.12 in. x 75°	" "	B1606
C	13 flutes 0.12 in. x 75°	Nose	B1607
D	13 flutes 0.18 in. x 75°	"	B1609
E*	13 flutes 0.12 in. x 75°	"	B1612

*Shell softened to 200 V.D.H.

Weights of original shells (including driving bands) and charges

	A	B1	B2	C	D	E
	lb. oz. dr.	lb. oz. dr.	lb. oz. dr.	lb. oz. dr.	lb. oz. dr.	lb. oz. dr.
Wt. of shell	10 6 6	10 5 8	10 6 2	10 6 6	10 6 12	10 7 12
Wt. of explosive	1 8 6	1 6 12	1 6 12	1 15 10	1 14 12	1 15 4

Number and weight of fragments in each class

Class, oz.	Number						Weight, oz.						Weight, per cent. of original shell.					
	A	B1	B2	C	D	E	A	B1	B2	C	D	E	A	B1	B2	C	D	E
2 - 4*	2	1	2	1	3	3	4.6	2.6	5.1	2.8	7.5	8.1	2.80	1.60	3.04	1.67	4.51	4.84
1 - 2	4	19	21	26	36	28	5.6	24.6	26.9	34.0	50.3	43.1	3.33	14.86	16.22	20.44	30.14	25.65
1/2 - 1	38	52	42	75	50	69	24.6	36.9	28.3	51.8	34.6	49.2	14.78	22.27	17.03	31.12	20.73	29.33
1/4 - 1/2	82	93	104	57	46	26	27.1	34.3	35.3	20.1	16.7	9.4	16.30	20.67	21.28	12.11	9.98	5.59
1/8 - 1/4	208	121	115	66	55	51	37.1	22.1	21.6	11.8	9.9	8.8	22.26	13.39	12.97	7.10	5.95	5.24
1/25 - 1/8	317	184	127	176	145	163	23.3	14.1	9.9	13.7	10.1	11.3	13.99	8.52	5.99	8.21	6.03	6.75
1/50 - 1/25	224	116	87	124	113	127	6.4	3.4	2.4	3.9	3.2	3.8	3.86	2.05	1.48	2.33	1.90	2.25
1/100- 1/50	237	162	101	163	172	180	3.6	2.3	1.4	2.4	2.4	2.6	2.16	1.38	0.85	1.44	1.42	1.56
Threaded nose							14.1	12.3	11.3	11.9	7.3	7.5	8.46	7.42	6.82	7.15	4.33	4.48
Copper band							11.8	11.4	11.8	11.1	11.9	13.4	7.08	6.88	7.11	6.68	7.11	7.97
Forward band+										0.9	0.8	0.6				0.57	0.47	0.33

*This class includes the disk from the base in all shots

+Not present on all shells

Sum of numbers and weights of fragments, excluding driving bands and nose

All fragments down to, oz.	Number						Weight, oz.						Weight, per cent. of original shell					
	A	B1	B2	C	D	E	A	B1	B2	C	D	E	A	B1	B2	C	D	E
2	2	1	2	1	3	3	4.6	2.6	5.1	2.8	7.5	8.1	2.80	1.60	3.04	1.67	4.51	4.84
1	6	20	23	27	39	31	10.2	27.2	32.0	36.8	57.8	51.2	6.13	16.46	19.26	22.11	34.65	30.49
1/2	44	72	65	102	89	100	34.8	64.1	60.3	88.6	92.4	100.4	20.91	38.73	36.29	53.23	55.38	59.82
1/4	126	165	169	159	135	126	61.9	98.4	95.6	108.7	109.1	109.8	37.21	59.40	57.57	65.34	65.36	65.41
1/8	334	286	284	225	190	177	99.0	120.5	117.2	120.5	119.0	118.6	59.47	72.79	70.54	72.44	71.31	70.65
1/25	651	470	411	401	335	340	122.3	134.6	127.1	134.2	129.1	129.9	73.46	81.31	76.53	80.65	77.34	77.40
1/50	875	586	498	525	448	467	128.7	138.0	129.5	138.1	132.3	133.7	77.32	83.36	78.01	82.98	79.24	79.65
1/100	1112	748	599	688	620	647	132.3	140.3	130.9	140.5	134.7	136.3	79.48	84.74	78.86	84.42	80.66	81.21

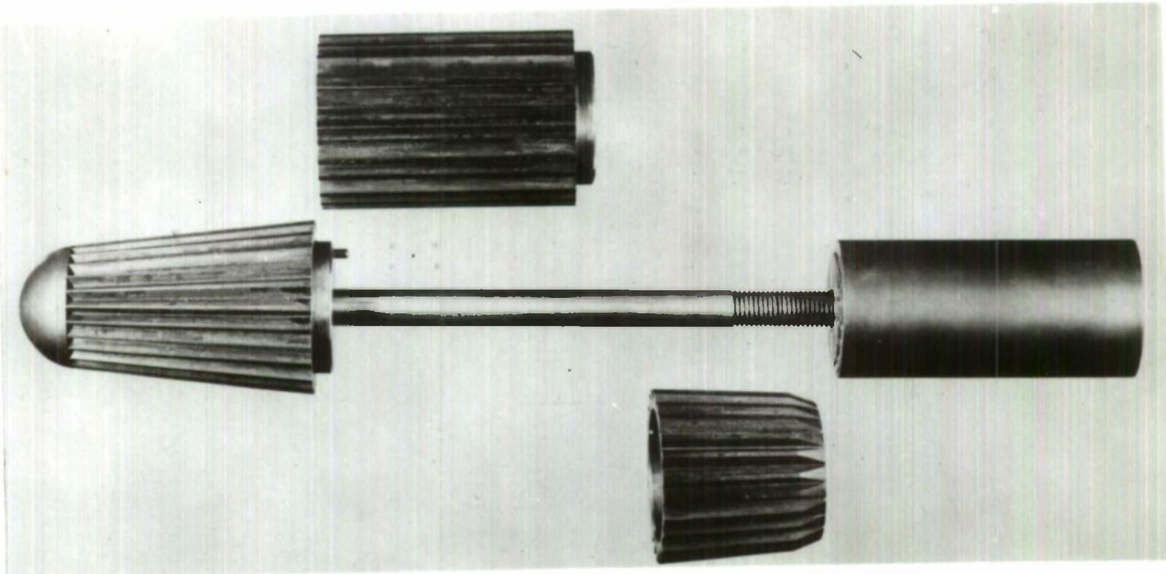

Fig.1(a) - Former: separate sections

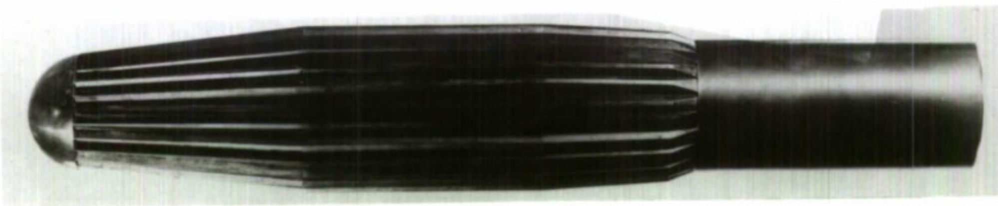

Fig.1(b) - Former: complete

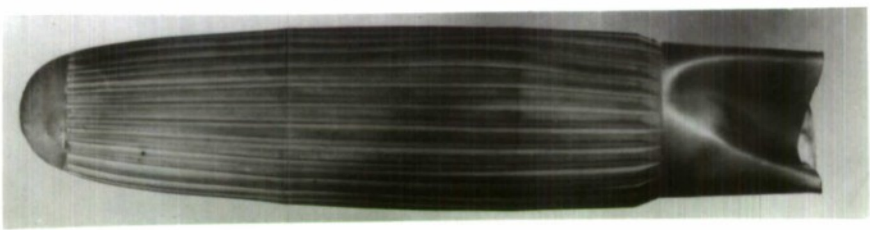

Fig.1(c) - Rubber liner

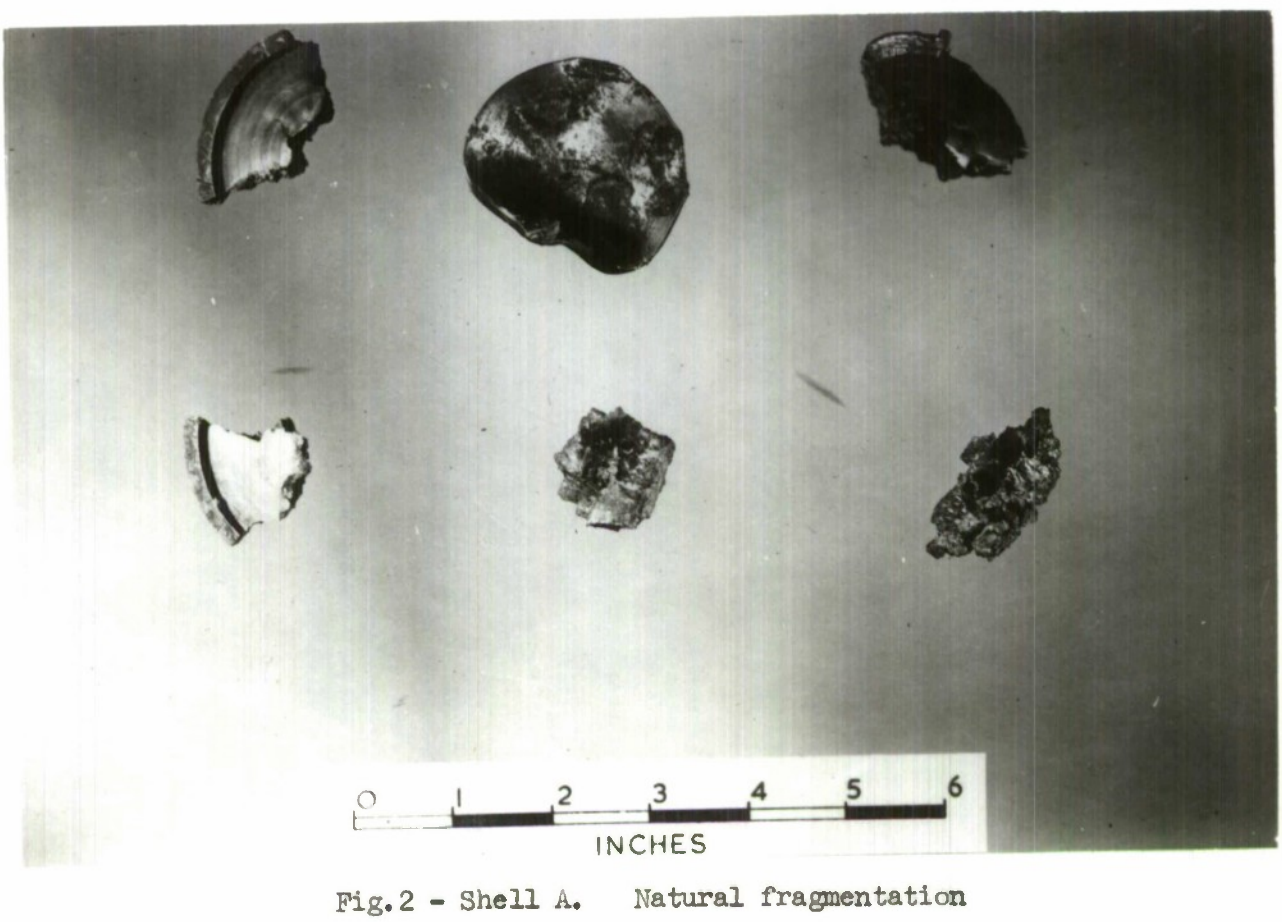

Fig.2 - Shell A. Natural fragmentation

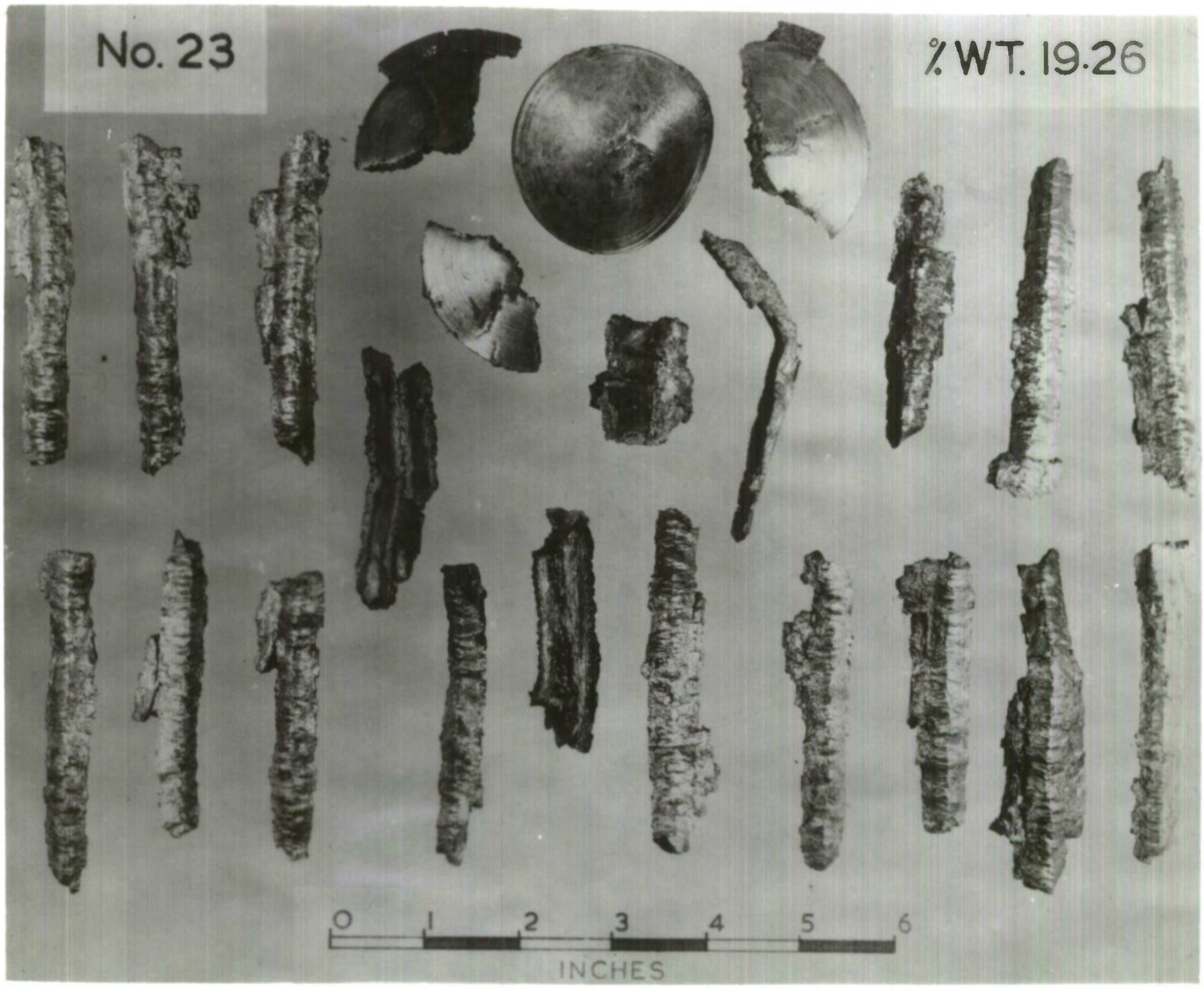

Fig.3 - Shell B2.   25 flutes 0.12 in. deep

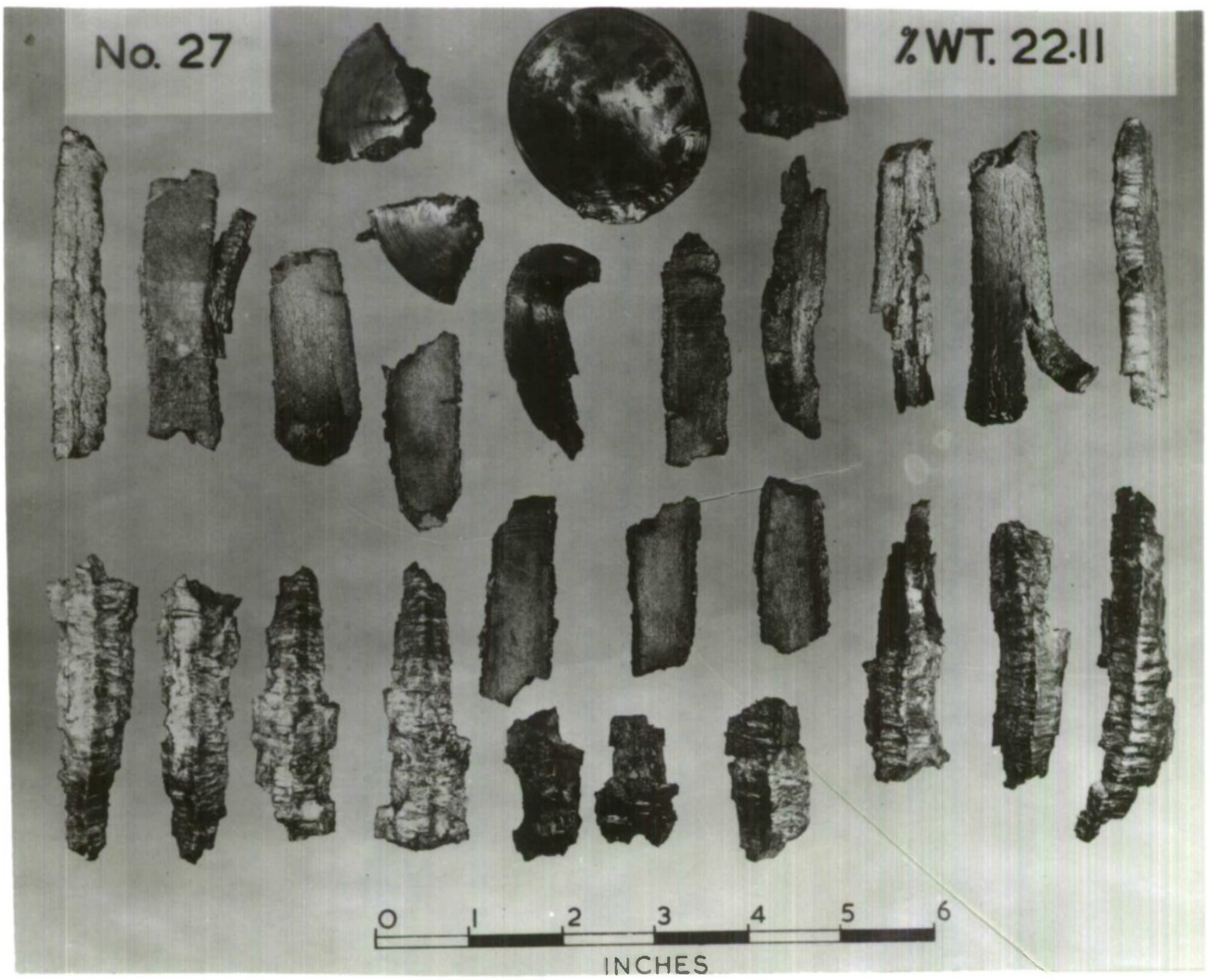

Fig.4 - Shell C.   13 flutes 0.12 in. deep

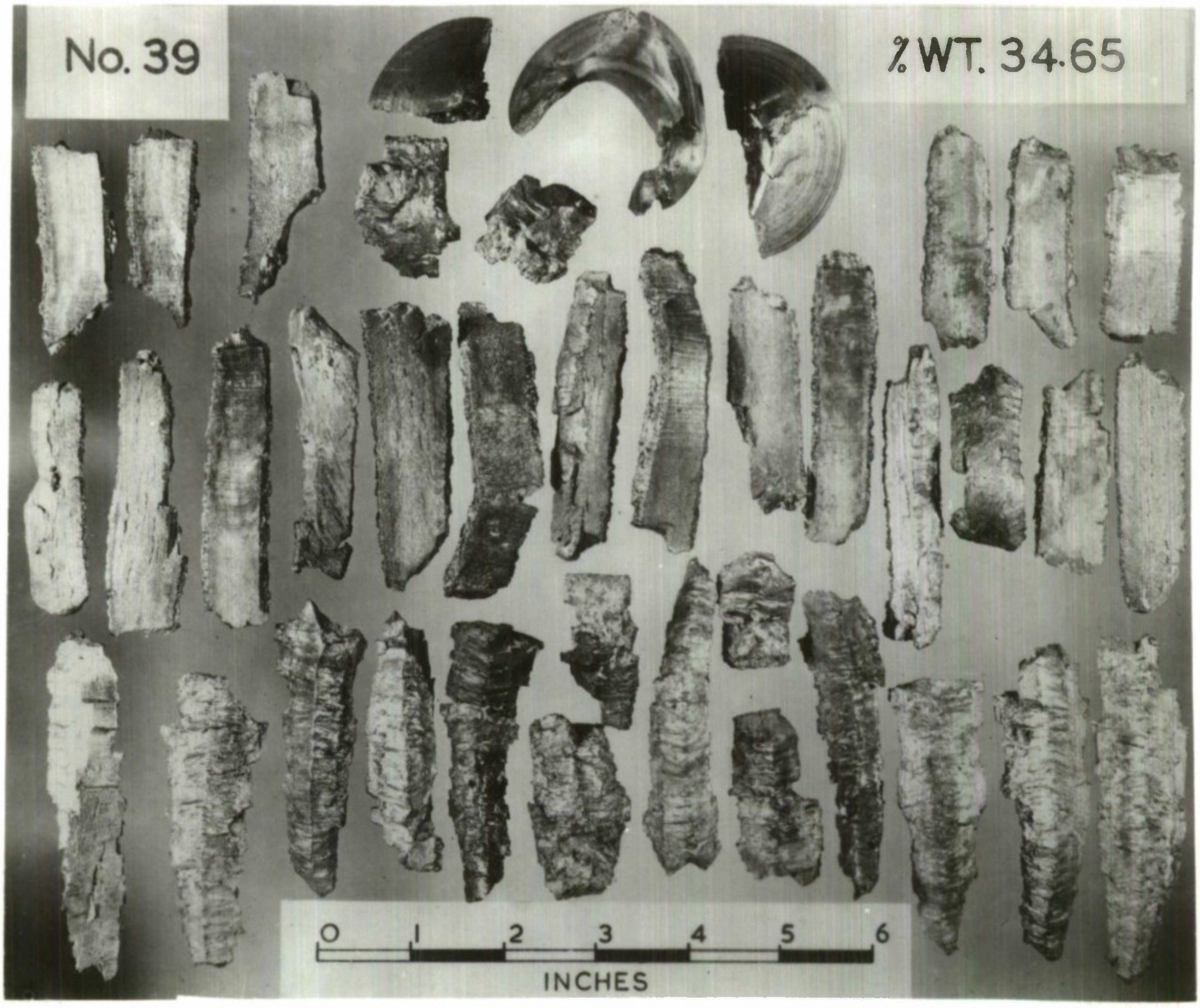

Fig. 5 - Shell D. 13 flutes 0.18 in. deep

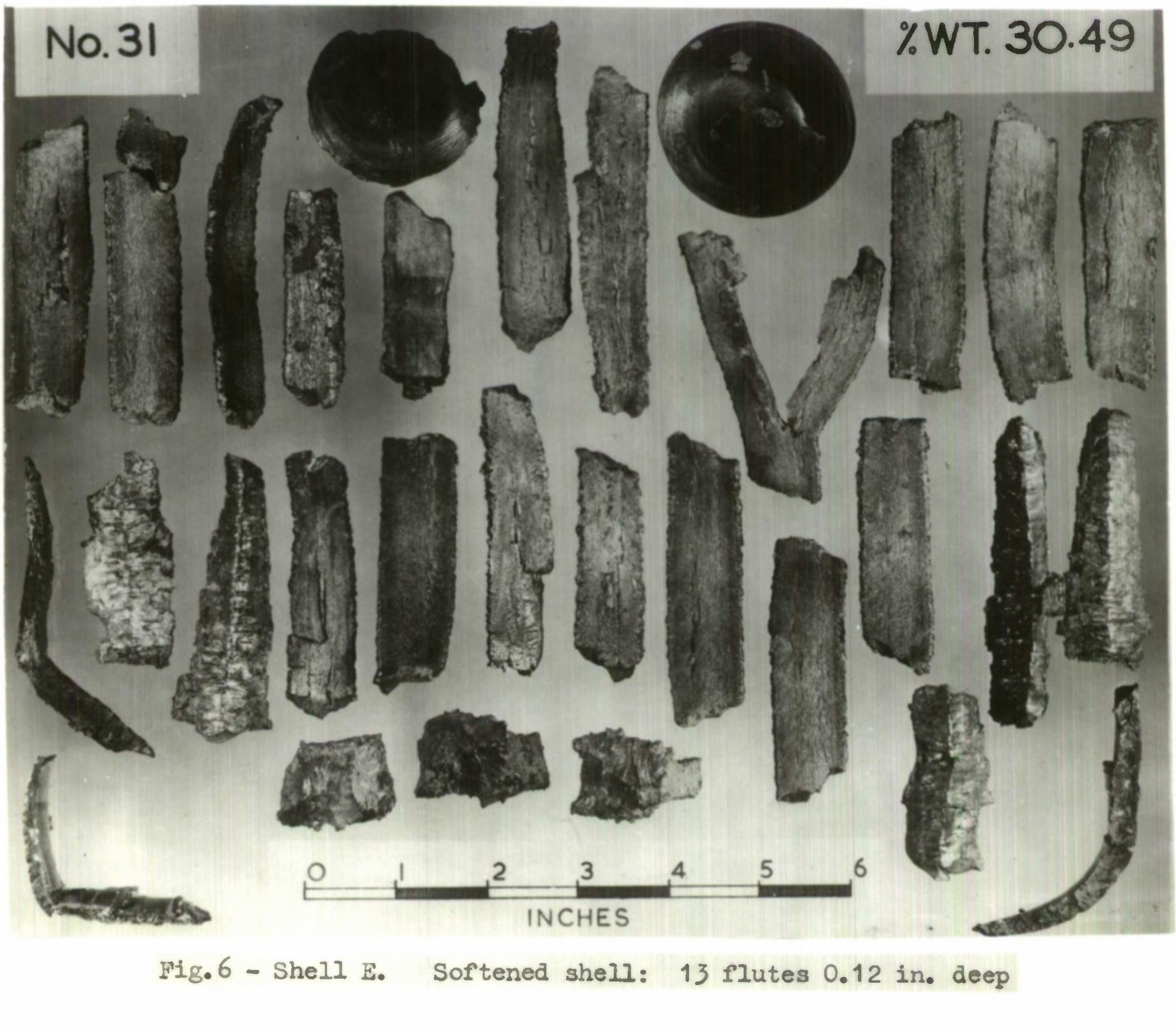

Fig. 6 - Shell E. Softened shell: 13 flutes 0.12 in. deep

ATI- 172 206

Safety in Mines, Research Establishment, Buxton, England (Buxton Report No. E.197)
CONTROLLED FRAGMENTATION XXXII - THE APPLICATION OF THE GROOVED-CHARGE PRINCIPLE TO SPIN-STABILISED SHELL, III - AND APPENDIX, by H. Titman and T.W. Taylor. May '52, 9 pp. incl. photos, tables. CONFIDENTIAL

The investigation into the application of the grooved-charge method of controlling fragmentation to spin-stabilized shell has been continued with the 3-in. 70 Cal shell to design D2(L) 5851/GE/880. An attempt has been made to obtain full-length bar

(over)

DIVISION: Ordnance and Armament (22)
SECTION: Ammunition (1)
PUBLISHED BY: Armament Research Establishment, Fort Halstead, England (Report No. 12/52)
DISTRIBUTION: Copies obtainable from ASTIA-DSC by U.S. Government Agencies only.

SECURITY INFORMATION
CONFIDENTIAL

1. Projectiles - Fragmentation
2. Projectiles, Spin-stabilized
I. Titman, H.
II. Taylor, T.W.

ATI- 172 206

fragments, but only half-length bars have been obtained. The failure was probably due to the presence of a forward driving band, but the results have also indicated a need for further research with parallel-walled canisters of similarly hard steel.

[dstl]

Information Centre
Knowledge Services
[dstl] Porton Down,
Salisbury
Wilts
SP4 0JQ
Tel: 01980-613753
Fax 01980-613970

Defense Technical Information Center (DTIC)
8725 John J. Kingman Road, Suit 0944
Fort Belvoir, VA 22060-6218
U.S.A.

AD#:
Date of Search: 16 February 2007

Record Summary:
Title: Controlled fragmentation XXXII: application of grooved-charge principle to spin stabilised shell, III
Covering dates 1952
Availability Open Document, Open Description, Normal Closure before FOI Act: 30 years
Former reference (Department) Report No 12/52
Held by The National Archives, Kew

This document is now available at the National Archives, Kew, Surrey, United Kingdom.

DTIC has checked the National Archives Catalogue website (http://www.nationalarchives.gov.uk) and found the document is available and releasable to the public.

Access to UK public records is governed by statute, namely the Public Records Act, 1958, and the Public Records Act, 1967.
The document has been released under the 30 year rule.
(The vast majority of records selected for permanent preservation are made available to the public when they are 30 years old. This is commonly referred to as the 30 year rule and was established by the Public Records Act of 1967).

This document may be treated as UNLIMITED.